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ECONOMIC PROBLEMS OF DETERMINING THE DURABILITY OF AIRCRAFT ENG--ETC(U)
JAN 77 V K VASHCHENKO, G M DERKACH

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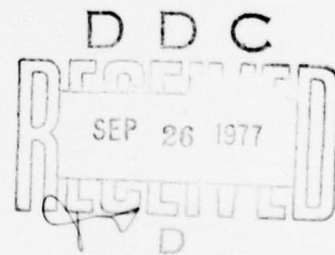
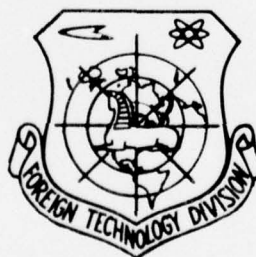
FOREIGN TECHNOLOGY DIVISION



ECONOMIC PROBLEMS OF DETERMINING
THE DURABILITY OF AIRCRAFT ENGINES

By

V. K. Vashchenko, G. M. Derkach



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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	<i>А а</i>	A, a	Р р	<i>Р р</i>	R, r
Б б	<i>Б б</i>	B, b	С с	<i>С с</i>	S, s
В в	<i>В в</i>	V, v	Т т	<i>Т т</i>	T, t
Г г	<i>Г г</i>	G, g	У у	<i>У у</i>	U, u
Д д	<i>Д д</i>	D, d	Ф ф	<i>Ф ф</i>	F, f
Е е	<i>Е е</i>	Ye, ye; E, e*	Х х	<i>Х х</i>	Kh, kh
Ж ж	<i>Ж ж</i>	Zh, zh	Ц ц	<i>Ц ц</i>	Ts, ts
З з	<i>З з</i>	Z, z	Ч ч	<i>Ч ч</i>	Ch, ch
И и	<i>И и</i>	I, i	Ш ш	<i>Ш ш</i>	Sh, sh
Й й	<i>Й й</i>	Y, y	Щ щ	<i>Щ щ</i>	Shch, shch
К к	<i>К к</i>	K, k	Ъ ъ	<i>Ъ ъ</i>	"
Л л	<i>Л л</i>	L, l	Ы ы	<i>Ы ы</i>	Y, y
М м	<i>М м</i>	M, m	Ь ь	<i>Ь ь</i>	'
Н н	<i>Н н</i>	N, n	Э э	<i>Э э</i>	E, e
О о	<i>О о</i>	O, o	Ю ю	<i>Ю ю</i>	Yu, yu
П п	<i>П п</i>	P, p	Я я	<i>Я я</i>	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
 When written as ё in Russian, transliterate as yë or ë.
 The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	Α α	•	Nu	Ν ν
Beta	Β β		Xi	Ξ ξ
Gamma	Γ γ		Omicron	Ο ο
Delta	Δ δ		Pi	Π π
Epsilon	Ε ε	•	Rho	Ρ ρ ϑ
Zeta	Ζ ζ		Sigma	Σ σ ς
Eta	Η η		Tau	Τ τ
Theta	Θ θ	•	Upsilon	Υ υ
Iota	Ι ι		Phi	Φ φ ϕ
Kappa	Κ κ	•	Chi	Χ χ
Lambda	Λ λ		Psi	Ψ ψ
Mu	Μ μ		Omega	Ω ω

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	\sin^{-1}
arc cos	\cos^{-1}
arc tg	\tan^{-1}
arc ctg	\cot^{-1}
arc sec	\sec^{-1}
arc cosec	\csc^{-1}
arc sh	\sinh^{-1}
arc ch	\cosh^{-1}
arc th	\tanh^{-1}
arc cth	\coth^{-1}
arc sch	sech^{-1}
arc csch	csch^{-1}
<hr/>	
rot	curl
lg	log

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ECONOMIC PROBLEMS OF DETERMINING THE DURABILITY OF AIRCRAFT ENGINES

V. K. Vashchenko and G. M. Derkach

Increasing the service life, reliability and maintainability of aircraft engines is a complex problem which involves design, technological, operational and economic problems. We will discuss the problem of establishing the optimum number of major overhauls of derivative engines with different service lives in the design stage.

The minimum calculated expenditures on an engine per hour of operation (3_{г.д}): can be used as the economic criterion for the preliminary determination of the optimum number of major overhauls of these engines:

$$Z_{q,d} = C_{q,d} + E_n \Phi_{q,d} \rightarrow \min, \quad (1)$$

where $C_{q,d}$ - the prime cost of the engine per hour of operation, rubles;

$\Phi_{q,d}$ - the fixed and circulating capital of the organization operating the engine, rubles;

E_n - the standard efficiency coefficient.

We will consider the dependence of these values on the number of major overhauls.

The prime cost of the engine per operating hour can be found by the formula:

$$C_{q,d} = \frac{C_A^0 + C_A + \sum_{i=1}^n C_{PI}}{\tau(n+1)} (1 + E_n) + A_3, \quad (2)$$

where C_A^0 - the expenditures on test and design work for one engine, rubles;

C_A - the prime cost for manufacturing the engine, rubles;

C_{pi} - the prime cost of a major engine overhaul, rubles;

n - the number of major overhauls;

A_2 - the operational expenses on servicing and fuel and lubricants consumed per hour of engine operation, rubles;

τ - the service life of the engine between overhauls, hours.

As formula (2) shows, only the prime repair cost depends on the number of major overhauls of an engine, and here not the entire prime cost, but only the expenditures on replaceable spare parts depend on this. These expenses are called standard variable expenses

(C_{ynp}) depending on the value of n .

The prime cost of a major overhaul

$$C_p = C_{yn} + C_{ynp} = C_{yn} + A + b_n n + b_1 \tau, \quad (3)$$

where C_{yn} - standard fixed expenditures, i.e., expenditures on repair without consideration of replaceable spare parts, rubles;

A - the equation parameter;

b_n, b_r - the coefficients of the increase in expenditures depending on the increase in n and r , respectively.

It follows from equation (3) that

$$\sum_{i=1}^n C_{pi} = C_{yn} n + \left[A + \frac{1}{2} b_n (n+1) + b_r r \right] n. \quad (4)$$

Expenditures on servicing and fuel and lubricants increase in proportion to the length of time the engine is in operation. These expenditures are fixed per hour of the engine's operation.

The greatest difficulty lies in determining the value of $\Phi_{a, \lambda}$:

$$\Phi_{a, \lambda} = \frac{\phi}{T_q}, \quad (5)$$

where ϕ - the annual fixed and circulating capital of the organization operating the engine, rubles;

T_q - the annual flying time of the aircraft, hours.

We will consider the change in the components of values ϕ with

the increase in the number of major engine overhauls at $r = \text{const.}$

The fixed and circulating capital of the organization operating the engine are composed of the capital of the repair shops and airports.

The fixed capital consists of the cost of their equipment, buildings and installations (including the aircraft maintenance base), as well as the aircraft and engine fleet, and the circulating capital - the cost of materials, spare parts, fuel, oil, etc.

Without consideration of the engine fleet, the absolute value of the fixed and circulating capital of repair shops and airports increases with the increase in the number of major overhauls of derivative engines with a given service life. Thus, as the volume of work on major overhauls and maintenance increases, more types of this work are done, which increases the amount of equipment needed to outfit the buildings, installations, and circulating capital.

There are virtually no procedures available for determining fixed and circulating capital. For a repair shop (ϕ_p) , their value can be approximated as follows:

$$\phi_p = \frac{\phi_{oc} + \phi_{oc}}{T_n} C_p = K_\phi C_p, \quad (6)$$

where ϕ_{oc}, ϕ_{oc} - the fixed and circulating capital of the shop, respectively, rubles;

T_n - commodity output, rubles;

K_ϕ - the fixed and circulating capital earned per ruble of commodity output.

Studies have shown that K_ϕ is close to one for different repair shops. For rough calculations, we can say that $K_\phi = 1$. Then $\phi_p = C_p$.

Even if its lower limit is projected, the repair cost provides the plant with a standard level of profitability, no matter what the number of repairs. Thus, when determining the optimum number of overhauls the standard level of profitability is accounted for in the repair cost in expenses per operating hour of the engine.

Different types of aircraft and engines with different service life derivatives are operated simultaneously at airports. Therefore,

it is very difficult to determine the fixed and circulating capital of airports without considering the aircraft fleet. The mean annual value of this capital can arbitrarily be considered to be fixed for rough calculations.

The fixed capital of airports also includes the cost of the engine fleet. The cost of a derivative engine with a particular service life is fixed. The annual engine requirement depends on the number of aircraft needed and the number of engines per aircraft. The number of aircraft depends on the annual transportation requirement.

Both the aircraft fleet (and, therefore, the number of engines as well) and their annual flying time increase as the volume of transportation increases. Consequently, the mean annual cost of the engine fleet per hour of operation will vary insignificantly, and can be considered to be fixed for approximate calculations.

Thus, we can also say that $\phi_{q,a} = \text{const.}$

We will expand formula (1), revealing the values which depend on the number of major engine overhauls:

$$3_{q,a} = \frac{C_a^0 + C_a + C_{yn} + \left[A + \frac{1}{2} b_n (n+1) + b_r \tau \right] n}{\tau (n+1)} \times \\ \times (1 + E_n) + A_s + E_n \phi_{q,a} = \text{min.} \quad (7)$$

Setting the first derivative of equation (7) equal to zero, we will obtain the formula for establishing the economically optimum number of **major overhauls** of a derivative engine with a particular service life (n_{on}):

$$n_{on} = \sqrt{2 \frac{C_A^0 + C_A(i_c) - C_{yn}(i_p) - A - b_r \tau}{b_n}} - 1, \quad (8)$$

where i_c and i_p are the sequential numbers of the quarters from the beginning of the series production of the engines and their repair, respectively.

As formula (8) shows, n_{on} depends on the ratio of expenditures on experimental design work and series production, as well as on repair expenses, which are affected by the time factor.

This makes it necessary to consider first-order obsolescence,

i.e., the depreciation of an engine through time. Therefore, we must find out when it is advisable to determine this value.

Actually, by the time a series-produced engine is overhauled, the prime cost of similar engine versions with the same service life has been reduced. In order to take this into consideration when determining the prime cost of manufacturing engines, it is necessary to account for the quarter corresponding to the time during which the engine was overhauled.

Furthermore, each subsequent major overhaul of the same engine is done after a specified period of time, which changes its prime cost both during series production and during repair. This must also be taken into consideration when determining -

The time between major engine overhauls (Δi) depends on the service life between repairs, the annual flying time of the aircraft, and the transportation and storage time:

$$\Delta i = \frac{4\tau}{T_q} + t, \quad (9)$$

where t is the engine transportation and storage time, in quarters.

The time between an engine's first major overhaul and any subsequent overhaul

$$M_n = \left(\frac{4\tau}{T_q} + t \right) (n-1). \quad (10)$$

Thus, in order to account for the effect of first-order obsolescence when determining n_{opt} , it is necessary to add the value of M_n to the number of the quarter of series production and repair in formula (8).

The figure shows the change in the value of the optimum number of overhauls of engines with different service lives between repairs ($\tau_1, \tau_2, \tau_3, \tau_4$), depending on the time the repairs are made. The expenditures on series production are not reduced as much during the period when the repair is begun as in the period of the adoption of production. The expenditures on repairing an engine with service life τ_1 between repairs decrease markedly during the period of the adoption of production; therefore, the value of n_{opt} markedly increases. After this period, expenditures on repair are reduced more gradually. Thus, the value of the optimum number of overhauls of engines with different service lives between repairs changes insignificantly (within 0.5 over an extended period). In essence, this means that the value of n_{opt} can be determined for any engine

at any time after the period of the adoption of this engine's repair process.

Second-order obsolescence also affects the value of the economically optimum number of major engine overhauls. An old engine depreciates as derivative engines with a longer service life between repairs appear. Both expenditures on series production and those on experimental design work related to designing the engine with the old service life "depreciate." With the condition of the equal profitableness of the use of the old and new service life versions in the national economy, the expenditures on experimental design work and series production for the two versions should be equal to:

$$\frac{C_{\text{дс}}^0 + C_{\text{дс}}}{\tau_{\text{с}}} = \frac{C_{\text{дн}}^0 + C_{\text{дн}}}{\tau_{\text{н}}}, \quad (11)$$

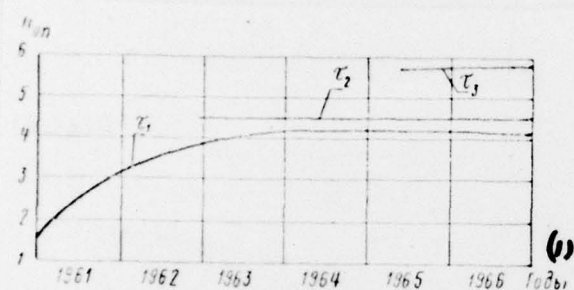
where **с** and **н** are subscripts designating the old and new service life versions of the engine, respectively.

Whence, with consideration of their depreciation, the expenditures related to the old service life version are:

$$C_{\text{дс}}^0 + C_{\text{дс}} = (C_{\text{дн}}^0 + C_{\text{дн}}) = \frac{\tau_{\text{с}}}{\tau_{\text{н}}}. \quad (12)$$

Figure. Change in the value of the optimum number of engine overhauls depending on the repair process time.

KEY: (1) Years.



Substituting expression (12) in equation (8), we obtain the formula for establishing the economically optimum number of major overhauls of derivative engines with a given service life with consideration of second-order obsolescence:

$$N_{opt} = \sqrt{\frac{(C_{\text{re}}^o + C_{\text{re}}) \frac{\tau_c}{\tau_n} - C_{\text{ync}} - A_c - b_{\text{ic}} \tau_c}{2 \frac{b_{\text{ac}}}{\tau_n}}} - 1. \quad (13)$$

Thus, the economically optimum number of major engine overhauls at $r = \text{const}$ must be determined during the period of the adoption of the repair process with consideration of the appearance of new service life derivatives.

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